AD NUMBER

ADB214862

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; Oct 73. Other requests shall be referred to Air Force Flight Dynamics Lab, [FEE], Wright-Patterson AFB, OH 45433.

AUTHORITY

AFRL notice dtd 11 May 2000

AFFDL-TM-73-136-FEE

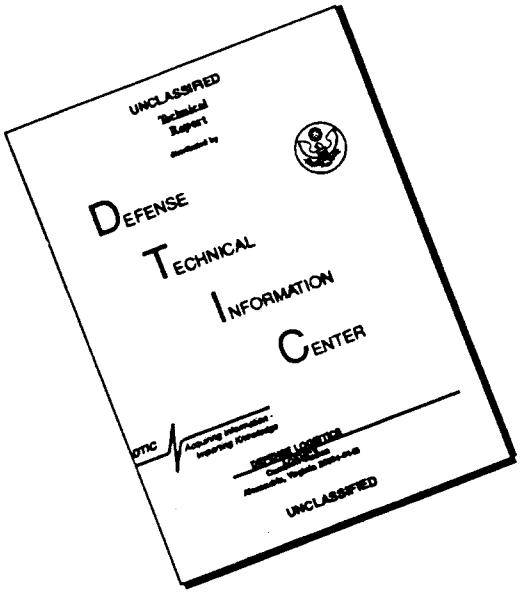
TEST EVALUATION OF THE C-5A EMERGENCY OXYGEN GENERATOR AS A POSSIBLE CAUSATIVE AGENT OF FIRES

EDWARD B. THOMPSON, JR

OCTOBER 1973

WRIGHT LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1973	Final October 1973

4. TITLE AND SUBTITLE
TEST AND EVALUATION OF THE C-5A EMERGENCY OXYGEN GENERATOR AS A POSSIBLE CAUSATIVE AGENT OF FIRES

5. FUNDING NUMBERS

6. AUTHOR(S)
EDWARD B THOMPSON JR

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AIR FORCE FLIGHT DYNAMICS LABORATORY
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE OH 45433

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AIR FORCE FLIGHT DYNAMICS LABORATORY
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFFDL-TM-73-136-FEE

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Distribution limited to U.S. Government agencies only; test and evaluation; statement applied October 1973. Other requests for this document must be referred to AF Flight Dynamics Laboratory, (FEE), Wright-Patterson AFB, OH 45433

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A fire occurred in an aircraft equipment storage depot at Travis AFB, California on 17 Aug 73. Post-fire investigations resulted in the tentative conclusion that the fire was caused either by arson or malfunction of C-5A emergency oxygen generators stored in the depot at the time.

The AFOSI was assigned the responsibility of conducting a complete investigation to determine the cause of the fire. This included a thorough evaluation of the C-5A emergency oxygen generator while operating under normal and abnormal conditions. Since the C-5A oxygen generator is a chlorate candle solid state device, the AFOSI requested the Environmental Control Branch of the Air Force Flight Dynamics Laboratory to conduct the experimental test program on the oxygen generator. AFOSI delivered approximately forty complete unfired generators and large quantities of fire debris to AFFDL at the initiation of the program. Discussions were subsequently held between AFFDL and other interested personnel in order to prepare a meaningful test plan. The plan agreed upon included eleven different types of tests. Most of the tests concerned the capability of the oxygen generator to self-actuate and then ignite adjacent combustible material while in storage. The remaining tests centered on gathering performance data on the generator and accessory material ignition temperatures in oxygen laden atmospheres. A final test was conducted around a reproduction of the conditions of the fire at Travis. The overall conclusion derived from the testing was that the oxygen generator could not have self-actuated and caused the fire.

14. SUBJECT TERMS	15. NUMBER OF PAGES
	50
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS

ABSTRACT

A fire occurred in an aircraft equipment storage depot at Travis AFB, California on 17 August 1973. Post-fire investigations resulted in the tentative conclusion that the fire was caused either by arson or malfunction of C-5A emergency oxygen generators stored in the depot at the time.

The Air Force Office of Special Investigation (AFOSI) was assigned the responsibility of conducting a complete investigation to determine the cause of the fire. The investigation included a thorough evaluation of the C-5A emergency oxygen generator while operating under normal and abnormal conditions. Since the C-5A oxygen generator is a chlorate candle solid state device, the AFOSI requested the Environmental Control Branch of the Air Force Flight Dynamics Laboratory to conduct the experimental test program on the oxygen generator.

AFOSI delivered approximately forty complete unfired generators and large quantities of fire debris to AFFDL at the initiation of the program. Discussions were subsequently held between AFFDL and other interested personnel in order to prepare a meaningful test plan.

The plan agreed upon included eleven different types of tests. Most of the tests concerned the capability of the oxygen generator to

self-actuate and then ignite adjacent combustible material while in storage. The remaining tests centered on gathering performance data on the generator and accessory material ignition temperatures in oxygen laden atmospheres. A final test was conducted around a reproduction of the conditions of the fire at Travis. One of six generators packaged in a carton was actuated after being placed within a large crate. The generator was set on fire and the developing fire pattern in the crate was observed and noted.

The overall conclusion derived from the testing was that the oxygen generator could not have self-actuated and caused the fire.

FOREWORD

This Technical Memorandum was prepared by the Air Force Flight Dynamics Laboratory, (AFFDL), Director of Research and Technology, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The test program described within this memorandum consisted of system support as documented under 75007031 in the Environmental Control Branch of the Air Force Flight Dynamics Laboratory. Mr. E. B. Thompson, Jr. was the principal investigator. Cooperating with Mr. Thompson in the endeavor were F. W. Thompson, Jr., J. B. Gisclard, Lt. P. Hinman, A. Civetz and R. Nawman of the Air Force Flight Dynamics Laboratory; and K. Calabrese and R. Mason of the Air Force Office of Special Investigation. Consultation and technical assistance was provided by Mr. A. Adduci of the Life Support SPO, and Mr. B. Chesterfield of the Military Airlift Command. Particular acknowledgement is given to B. Botteri, R. Cretcher and G. Gandee of the Air Force Aero Propulsion Laboratory for their assistance and concurrence in the test results.

This memorandum summarizes the results of tests conducted to determine if the C-5A emergency oxygen generator had caused a fire to occur at Travis AFB, California on 17 August 1973. The type of tests conducted included: standard performance data on oxygen flowrate and purity; thermal data on housing temperature and autoignition temperatures of proximate materials; simulated housing burn-through tests; and severe

vibration levels to effect generator self-ignition. A summary experiment was also conducted in which pre-existing fire conditions were reconstructed and ignited by a modified oxygen generator.

The manuscript was released by the author in October 1973 for publication as a Technical Memorandum.

This Technical Memorandum has been reviewed and is approved.

WILLIAM C. SAVAGE
Chief, Environmental Control Branch
Vehicle Equipment Division

I. INTRODUCTION:

On the 17th of August 1973, a fire occurred in an aircraft equipment storage building at Travis AFB, California. The fire apparently started in or on the bottom crate of a stack of crates located in the corner of the building. The approximate time that the fire began was 1330 to 1400 hours. The circumstances surrounding the fire were such that there were grounds for suspecting arson. The equipment stored within the building was accessory to the C-5A transport, consisting of troop transport seat pallets and chlorate candle emergency oxygen generation devices. There had been a scheduled fire and safety inspection of the building on the preceding day (16 Aug 73) and yet on 17 Aug 73 at 1000 hours two unidentified "inspectors" approached the building custodian and announced they were making a "fire" inspection*. This inspection was conducted without the custodian since he was detained in his office by telephone calls. The inspectors left the building at approximately 1020 hours without speaking to the custodian or reporting back to him on the building's safety status.

The fire broke out several hours later. Several other identifiable personnel had been in the building between 1020 and 1330 hours but failed to detect any smoke or odor coming from the stack of crates. When the flames were first seen, they were engulfing the entire stack and had, in fact, reached the windows located high on the building wall.

*The two inspectors had not been identified or located as of the publication date of this Technical Memorandum.

The fire department was contacted immediately and extinguished the blaze without further damage.

The Air Force Office of Special Investigation at Travis AFB undertook to investigate the entire matter. The investigation led to two possible causes of the fire. The first, arson, has already been discussed and in fact is still being investigated by AFOSI. The second possible cause was the self-actuation of one of the chlorate candle oxygen generators located inside the bottom crate in the stack. The hypothesis was that if arson was not the cause, then the oxygen generators packaged inside the crates had somehow actuated, the heat from which subsequently ignited the surrounding combustible material. The basis of the theory proceeded on the assumption that the generator(s) had self-actuated.

AFOSI requested the Environmental Control Branch of the Air Force Flight Dynamics Laboratory (AFFDL/FEE) to undertake a test program to determine if it were possible for the generator(s) to have self-actuated and started the fire. AFOSI approaches to other government agencies for laboratory testing support had meanwhile proven futile.

AFFDL/FEE conferred with AFOSI and other interested USAF personnel in order to plan and carry out a meaningful test and evaluation program. Special Agent, Kent Calabrese, AFOSI - Travis AFB, personally delivered to AFFDL/FEE the bulk of material evidence from the fire as well as numerous C-5A oxygen generation devices. The program then proceeded from the date of delivery of the material.

II. PLANNING OF TEST PROGRAM:

AFFDL/FEE convened on 20-21 September 1973 with other interested USAF offices to discuss and plan the test program. The parties present at this conference are listed as follows:

F. W. Thompson, Jr.	AFFDL/FEE
E. B. Thompson, Jr.	AFFDL/FEE
J. B. Gisclard	AFFDL/FEE
A. Civetz	AFFDL/FEE
R. Nawman	AFFDL/FEE
K. Calabrese	AFOSI/Travis AFB
A. Adduci	ASD/SML
R. Govenar	ASD/ENCCE
B. Botteri	AFAPL/SFH
R. Cretcher	AFAPL/SFH
G. Gandee	AFAPL/SFH
B. Chesterfield	MAC IG/Scott AFB
G. Martin	OCAMA
D. Thompson	OCAMA

It was initially agreed that Ed Thompson would primarily conduct the test program because of his extensive experience with chlorate candle oxygen generation devices including the C-5A unit. Other parties would work with or under his direction.

The central problem discussed at the conference was what type of tests would be the most indicative as to the capability of the generator to self-actuate. The environmental conditions present in the storage

building at Travis AFB on 17 August 1973 were discussed with the question of relating air temperatures and vibration (due to aircraft taxiing past the building) to possible self-actuation. Possible heat build-up inside the crates (thereby causing the generator(s) to actuate was mentioned and discarded as being unrealistic.

The general theme of the conference discussion gradually narrowed down to agreement on three general types of tests to be conducted. These were:

- Tests to determine if a generator packaged for shipment could self-actuate and while operating cause ignition of plastics used in the generator housing/mask assembly or packaging materials.

- Tests to determine self-actuation temperature of the oxygen generator and associated materials.

- Tests to determine the behavior of a malfunctioning generator and its ability to cause ignition of proximate materials or equipment.

In addition to these three types of tests, it was decided to obtain an up-to-date set of performance and thermal characteristics of the C-5A oxygen generator. This information would be included in the test report.

It was also agreed that a general test simulating the fire (and pre-existing conditions) would be conducted at the conclusion of the program.

The fire would be started by a "malfunctioning" generator inside of a wooden crate with environmental conditions held as closely as possible to those at Travis AFB on 17 August 1973.

In summary, the conference discussions produced the following list of specific tests to be conducted:

1. A vibration test of a completely packaged generator wherein gunfire/random levels would be imposed on a unit to determine if the retaining spring on the Bouchon igniter could be jarred loose, thereby activating the generator accidentally.

2. A simulated "burn-through" of a generator wherein one of the two primers is removed; the other primer then activated to determine if the packaged unit would catch fire due to the flame cone from the primer opening.

3. Actuation of a generator while completely packaged to determine if the exothermic heat would ignite the mask assembly or packaging material.

4. Determination of the self-actuation temperature by a generator by placing a unit in an oven until activation is achieved.

5. Determination of the shell temperature profile of a generator through use of thermocouples while unit is operating.

6. Subjecting a packaged unit to extremely rough handling (shock, drop, etc.), remove generator from package, activate and observe performance.

7. Activation of a generator and the recording of record oxygen flowrate and purity.

8. Activation of a generator while packaged in proximity to other units to determine if the exothermic heat will ignite the adjacent generators.

9. Exposing of fire debris samples to vacuum, analysis of out-gas product for hydrocarbon content. Possibility of foreign material among debris might be discernible.

10. Activation of a unit with mask assembly in place in the generator housing. Allow oxygen to flow into mask housing recess, draw off gas specimens and determine the oxygen concentration. Concentration of oxygen will determine reduction of ignition temperature of mask materials.

11. Re-construction of the pre-existing fire conditions using a plywood wooden crate containing plastic sheeting and a carton with six packaged generators. Modify one of the six generators so that when activated a fire would begin in the mask assembly. This, in turn, would ignite the packaging material and eventually the plywood crate. The pattern of the developing fire could then be compared to the incident at Travis AFB.

All of the above tests would be implemented in a timely order appropriate to efficient use of laboratory facilities and personnel skills.

III. TEST PROGRAM

The test schedule as outlined in the preceding section proceeded according to plan. Immediately after the planning conference adjourned the necessary equipment and laboratory facilities were prepared and packaged generators laid out for test. Figure 1 depicts an unpackaged C-5A oxygen generator and components. The following tests were then conducted as described (but not necessarily in the listed order):

Test #1 - Two packaged generators were separately installed on a vibration table, each in a different plane as shown in the schematic in Figure 2. Vibration levels were simulated according to the following sequence:

1. Each generator was vibrated at 1/2" constant displacement over a range of 5-8 cycles. Generators did not self-activate nor was there any apparent damage to the units.

2. Each generator was subjected to 1 1/2 g's at 8 cycles with the "g" load maintained up to 200 cycles. No self-actuation or damage was noted.

3. Each generator was vibrated at 3/4" displacement over a range of 5-12 cycles. The generators were then subjected to 5 g's through frequencies of 12 to 500 cycles. No self-actuation or damage was noted. The generators were then held at 5 g's with the frequency varied randomly from 500 down

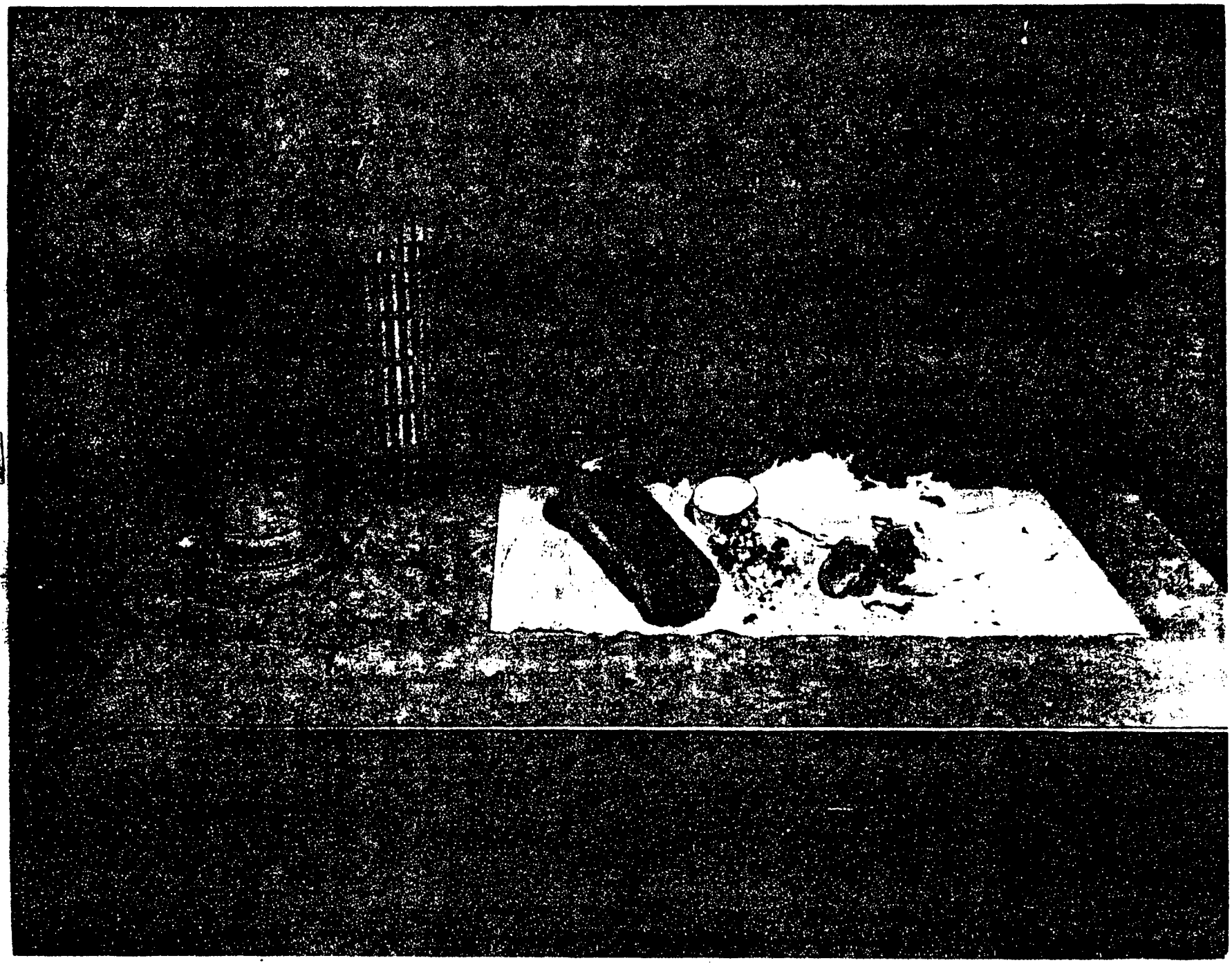


FIGURE 1 - C-5A Generator and Component Parts

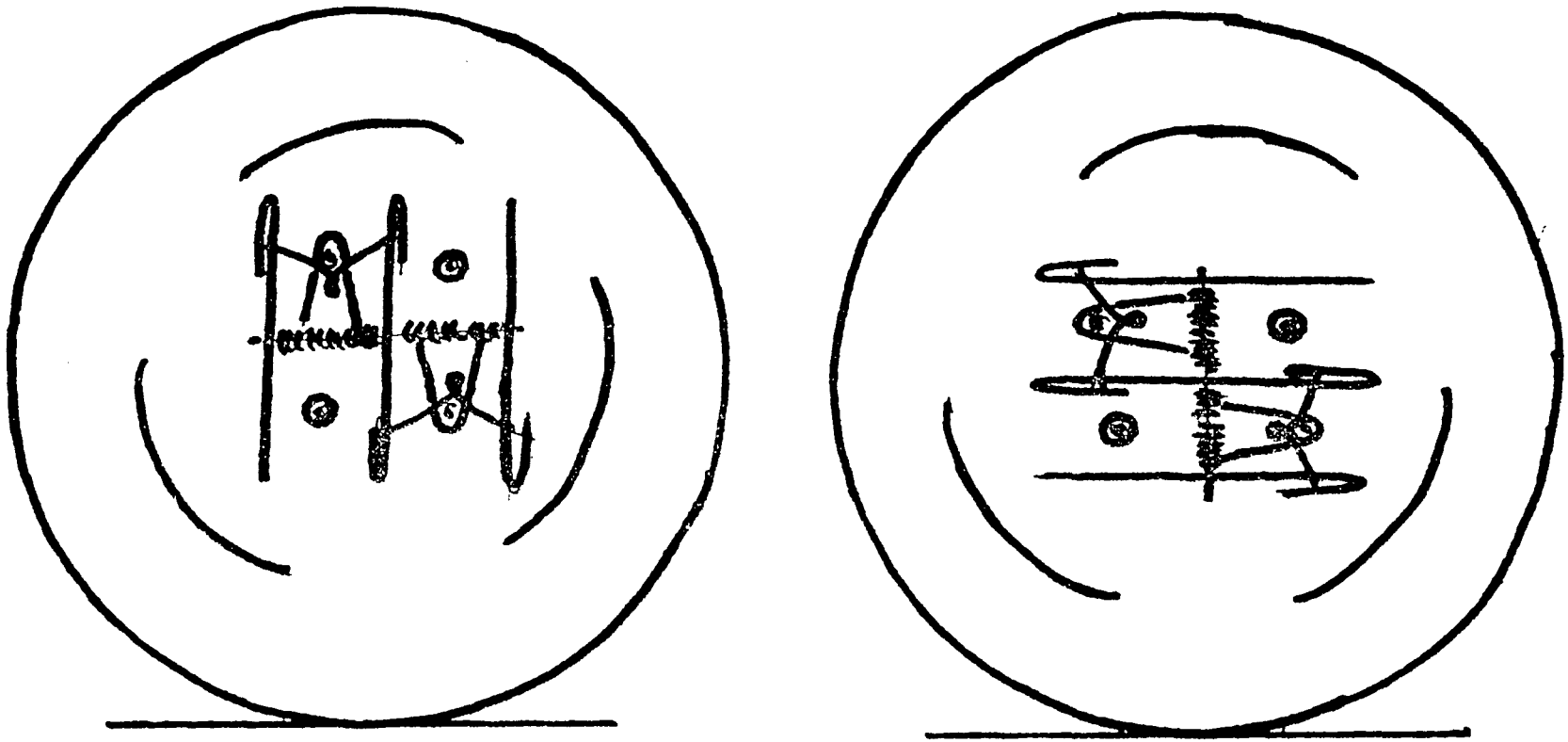


FIGURE 2 - Generators Positioned for Vibration Test

to 20 cycles. Resonant points were not discovered. No damage or self-actuation was noted.

Summarizing this test, the retaining springs which hold the Bouchon hammers in place and away from the ignition primers did not come loose regardless of the vibration load imposed. It was the qualitative opinion of the test monitor, Mr. Robert Sevy, that the generator(s) retaining springs could not accidentally dislodge when subjected to prolonged and random vibration levels.

Test #2 - One of the two ignition primers of a generator was completely removed, thereby, exposing the flash powder layer at the end of the candle. The generator was then re-packaged with the lanyard to the remaining primer drawn through the cardboard carton (Figure 3). The mask assembly remained in place in the recess in the generator housing. The generator was then activated. A fire started in the carton within thirty seconds and after ninety seconds one end of the package was burning (Figures 4, 5, and 6). The fire was extinguished immediately, the generator continuing to operate until the candle was consumed (Figure 7).

This test established the fact that a fire could be started within the generator packaging if one primer were missing and the other was activated. The likelihood of this combination occurring in a single generator is extremely improbable. Such a case never having been noted in the C-5A (or any other) generators received by this laboratory from vendors.

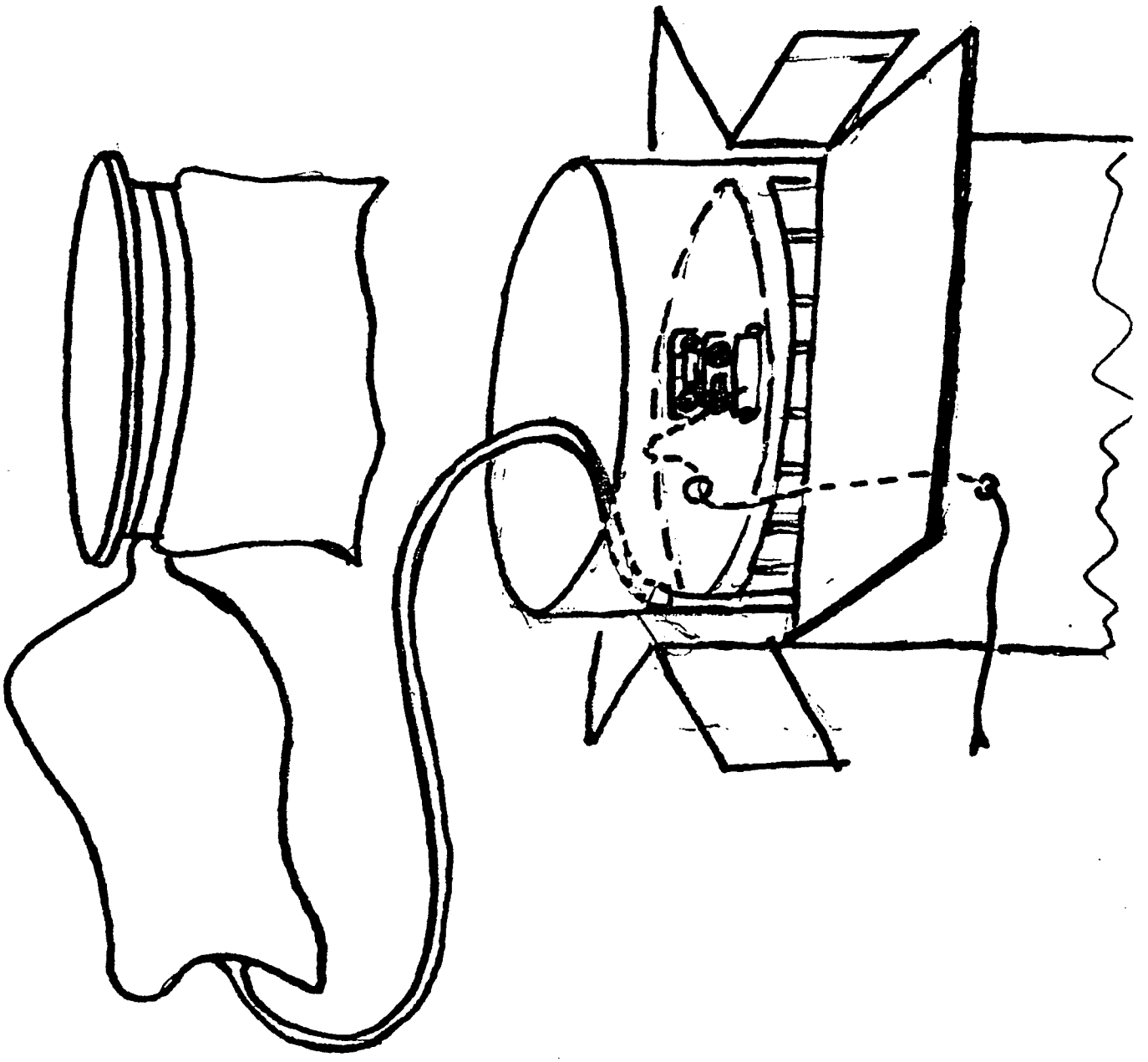


FIGURE 3 - "Malfunctioning" Generator Prepared for Test

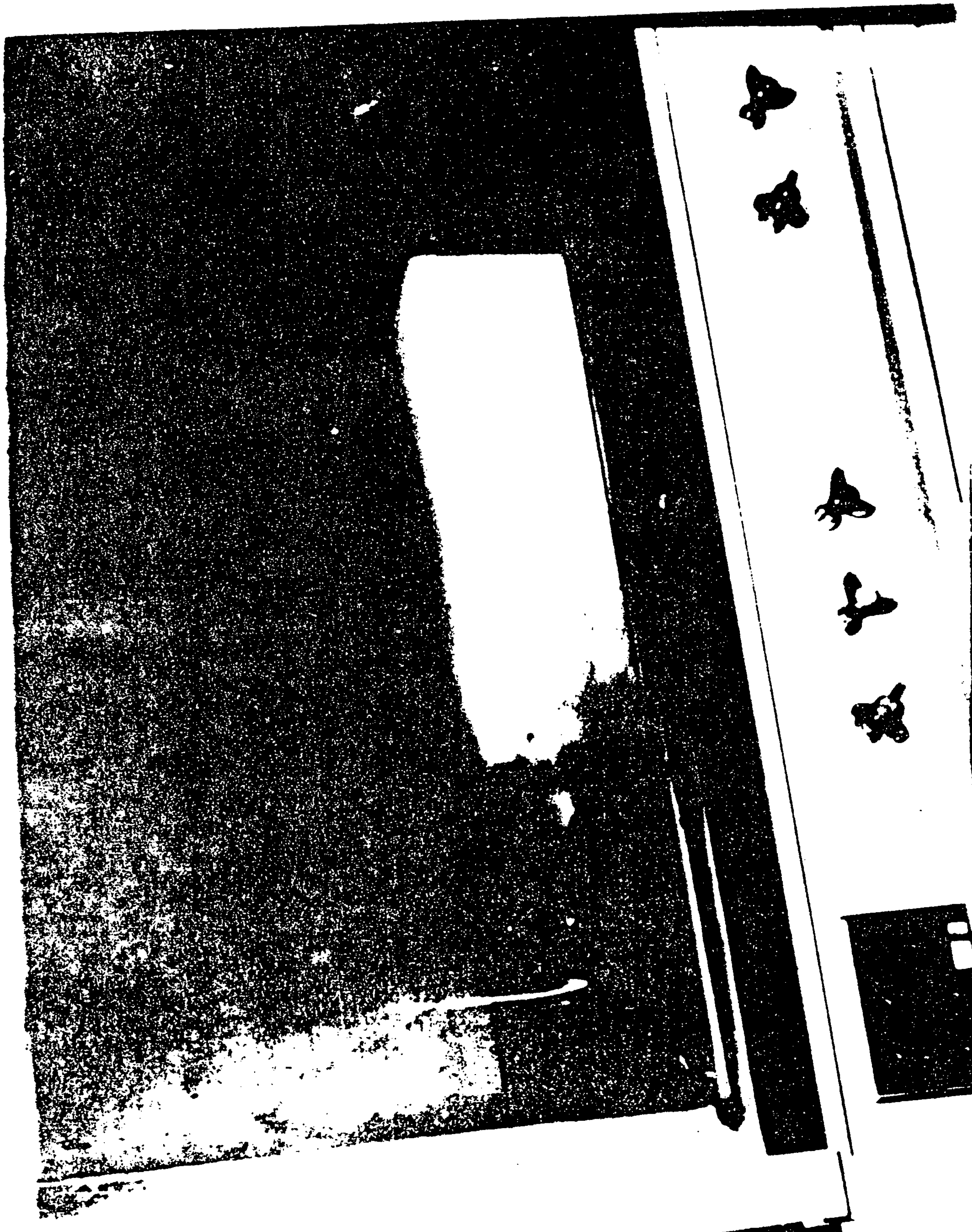


FIGURE [illegible] Carton Tested During Test

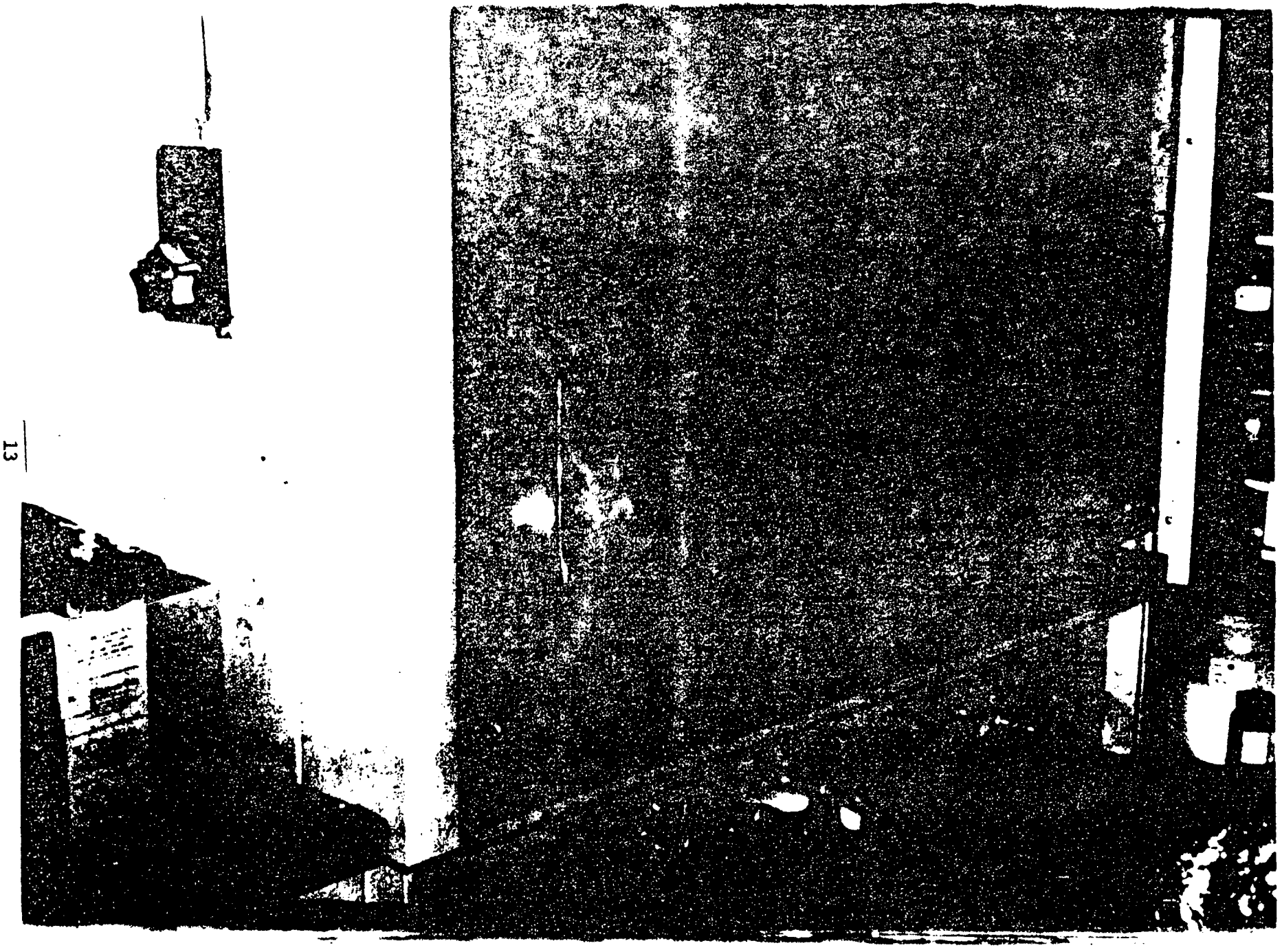


FIGURE 5 - Initial Appearance of Flame from Carton

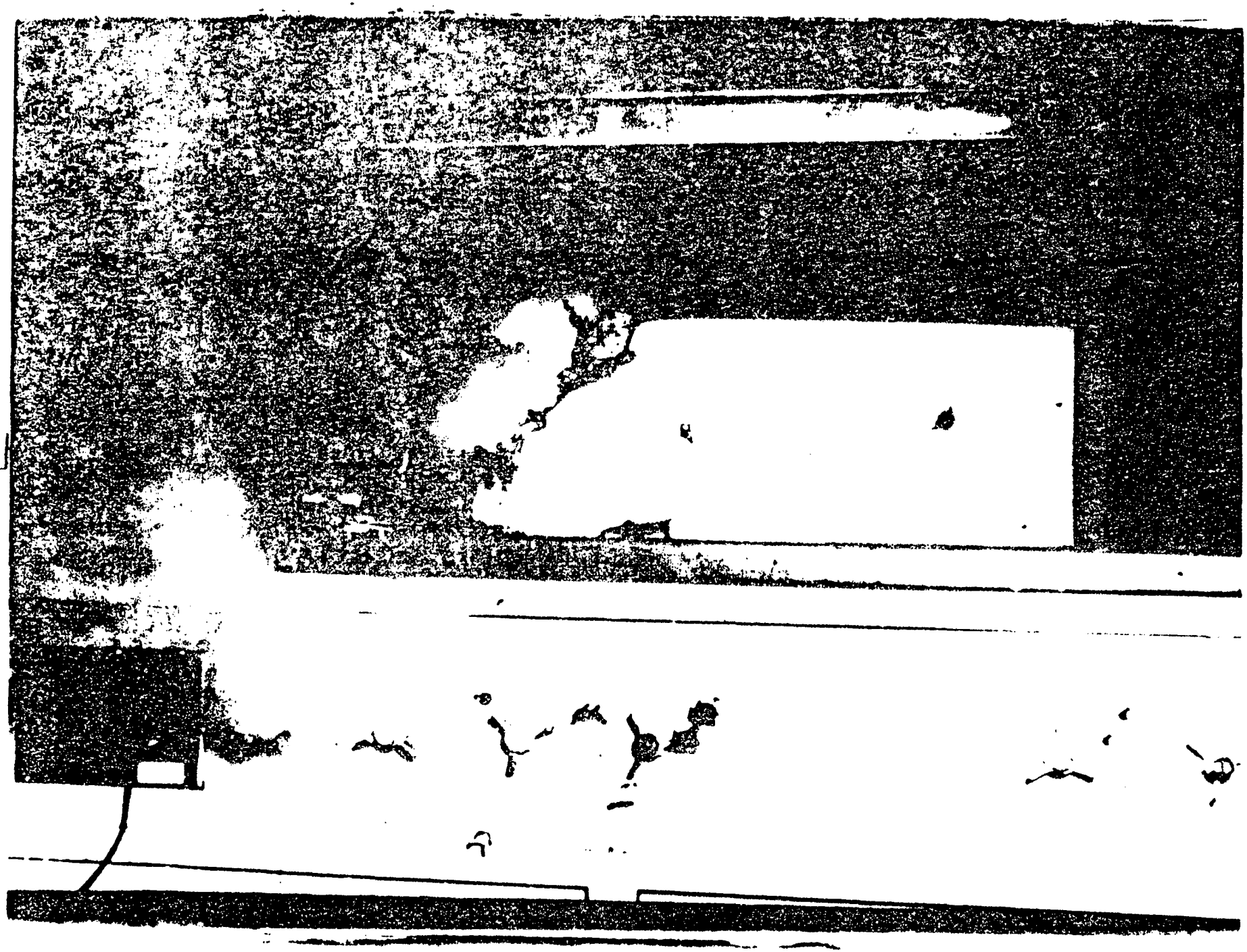


FIGURE 6 - Carton Burning Freely

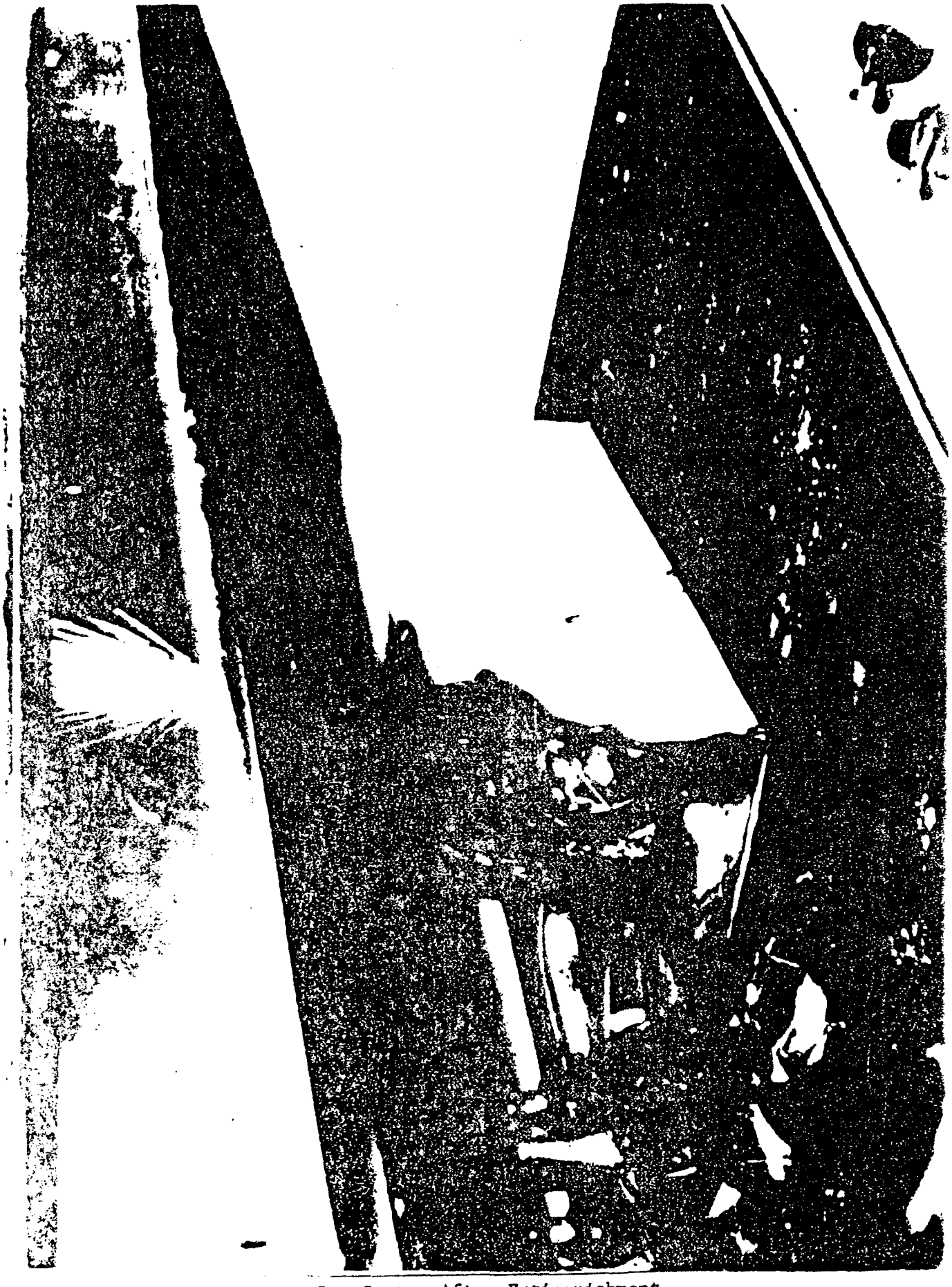


FIGURE 7 - Carton After Extinguishment

Test #3 - A packaged generator was modified so that an igniter lanyard was drawn through the housing and packaging carton (Refer to Figure 3). The other primer was left undisturbed. The generator was then activated and allowed to operate thirty-four minutes until the candle was consumed. The carton did become warm to the touch throughout the test but did not burst into flames. Upon inspection afterwards, it was noted that part of the tygon hose leading from the housing to the mask had melted. (Figure 8).

This test was repeated twice with the same result, that being that the exothermic heat from a normally operating generator is not sufficient to cause a fire in adjacent material such as the mask assembly or packaging carton.

Test #4 - A replacement cartridge for the oxygen generator was placed in an electric resistance oven. The oven temperature was increased 50° every four hours from a starting temperature of $150^{\circ}F$. When the oven temperature reached $300^{\circ}F$, the temperature was increased by 5° increments each hour. Self-actuation was achieved at $315^{\circ}F$. (Reference data had specified self-actuation at $320^{\circ}F$.)

This test verified the reference temperature for self-actuation as induced by an external heat source.

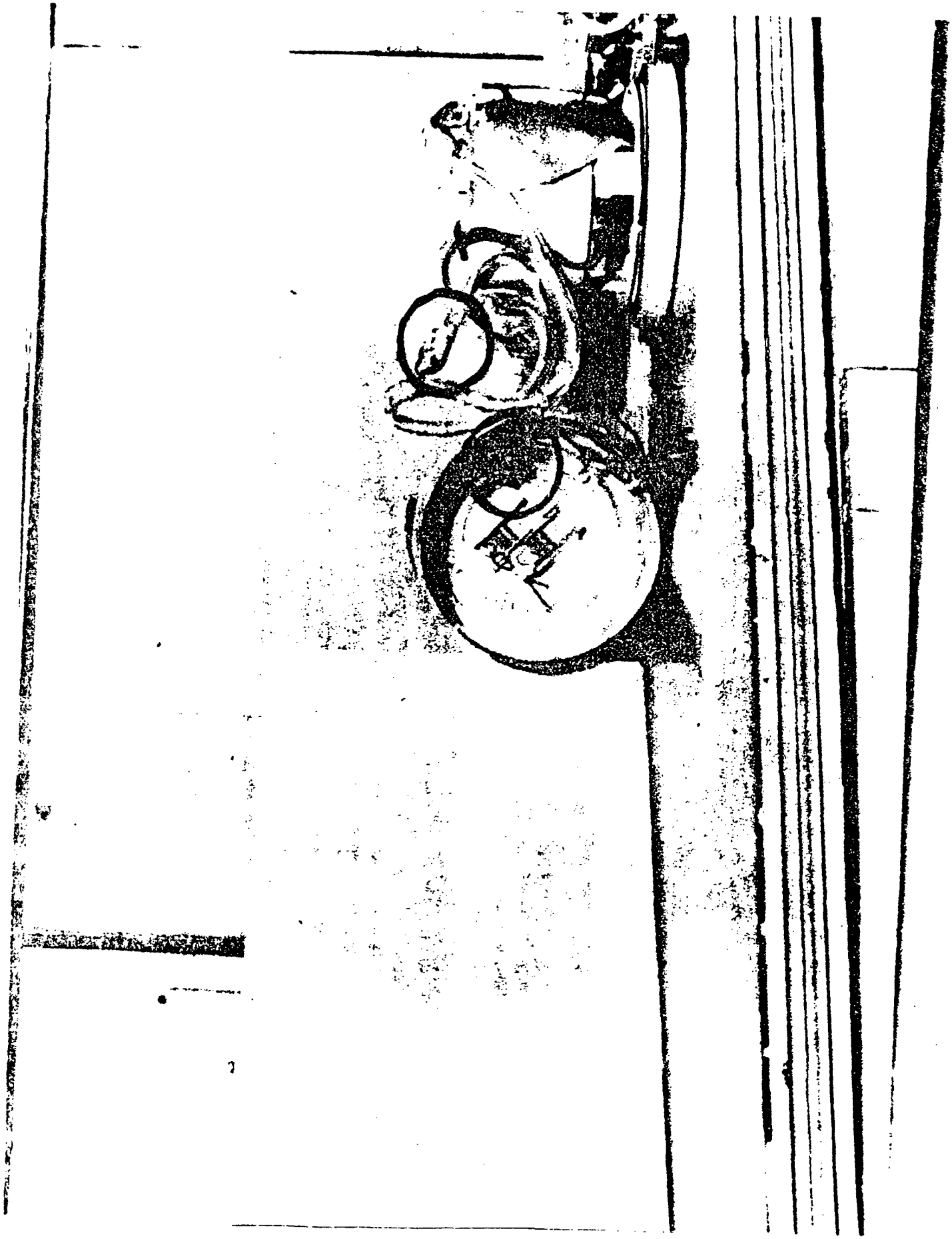


FIGURE 8 - Melted Tygon Hose - After Test

Test #5 - Several iron-constantan thermocouples were attached to the replacement cartridge of a generator. Figure 9 illustrates schematically the locations of the thermocouples as attached. The unit was activated and the following time-temperature data recorded:

Time (minutes)	Temperature (85°F - Pre-Test)			
	1	2	3	4
1	498	290	112	87
2	535	354	136	92
3	555	395	148	100
4	*557	435	155	101
5	548	457	158	103
6	535	465	159	103
7	520	470	156	103
8	505	472	155	103
9	490	472	155	103
10	475	472	156	104
11	460	475	156	104
12	446	*480	170	104
13	434	479	175	105
14	421	477	183	105
15	411	475	191	105
16	402	470	200	105
17	391	461	217	107
18	380	452	227	107
19	371	443	256	107
20	360	432	285	108

*Indicates highest temperature recorded for this position.

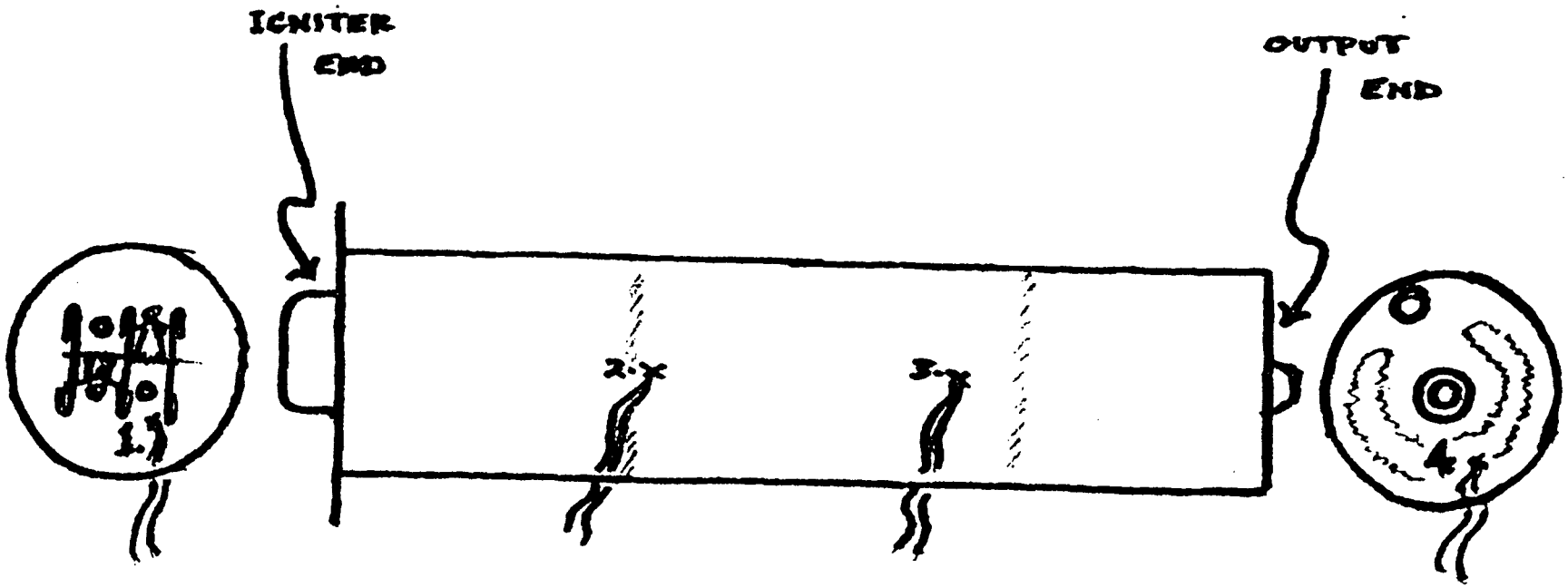


FIGURE 9 - Positions of Thermocouples on Generator

Time (minutes) continued	Temperature (85°F - Pre-Test) continued			
	1	2	3	4
21	350	425	280	110
22	341	415	286	110
23	334	403	338	111
24	325	392	348	112
25	316	381	357	112
26	309	373	380	112
27	300	365	393	113
28	290	355	405	113
29	285	348	410	115
30	280	340	421	117
31	272	332	*428	117
32	267	325	428	119
33	261	316	420	121
34	255	310	420	123
35	250	303	420	126
36	245	296	420	132
37	240	290	416	142
38	235	284	410	156 candl expende
39	232	279	406	184
40	224	272	400	188

Test #6 - A packaged generator was subjected to extremely rough handling for fifteen minutes which included a 20 ft. drop test. This test was

intended to simulate a situation in which careless field personnel would damage a generator through reckless and/or negligent handling. Despite the treatment accorded the unit and the external damage inflicted however, the generator operated normally after ignition.

This result established the fact that severe mistreatment of a generator does not necessarily impair its ability to operate normally.

Test #7 - A generator was equipped with a flowmeter and timer and then activated. The oxygen flowrate data recorded is listed as follows:

Time (minutes)	Flowrate (lpm)
1	9.5
2	11.3
3	6.8
4	5.9
5	6.1
6	5.2
7	4.9
8	5.1
9	4.6
10	4.2
11	4.7
12	4.4
13	4.1
14	4.2
15	4.3

Time (minutes)	(continued)	Flowrate (lpm)
16		4.0
17		4.8
18		5.1
19		4.3
20		4.7
21		4.1
22		4.6
23		5.0
24		4.9
25		4.3
26		4.6
27		4.8
28		4.2
29		4.0
30		4.7
31		5.6
32		6.2
33		2.2
34		Termination

The flowrate data as recorded above agreed with previous laboratory experience with C-5A oxygen generators.

The percentage of oxygen was also recorded from the time of the initial start-up until the candle was depleted. The total time was 34 minutes during which 100% oxygen was recorded for 29 minutes, dropping

off to 50% at the end of 30 minutes with no response at the end of 34 minutes. These findings indicate typical candle behavior from the standpoint of oxygen output.

Test #8 - A carton containing six packaged generators was selected. One of the packaged generators was outfitted with two thermocouples (on the outside of the package) as depicted in Figure 10. The generator was then re-inserted in the carton with a primer lanyard drawn through the carton and activated. Temperature data which was recorded through the duration of generator operation is listed as follows:

Time (after ignition)	T.C. 1	T.C. 2
2 minutes	80°F	80°F
4	79	75
6	82	81
8	86	84
10	89	88
12	94	94
14	99	100
16	104	104
18	108	109
20	110	114
22	115	116
24	119	120
26	122	123
28	125	126
30	130	131

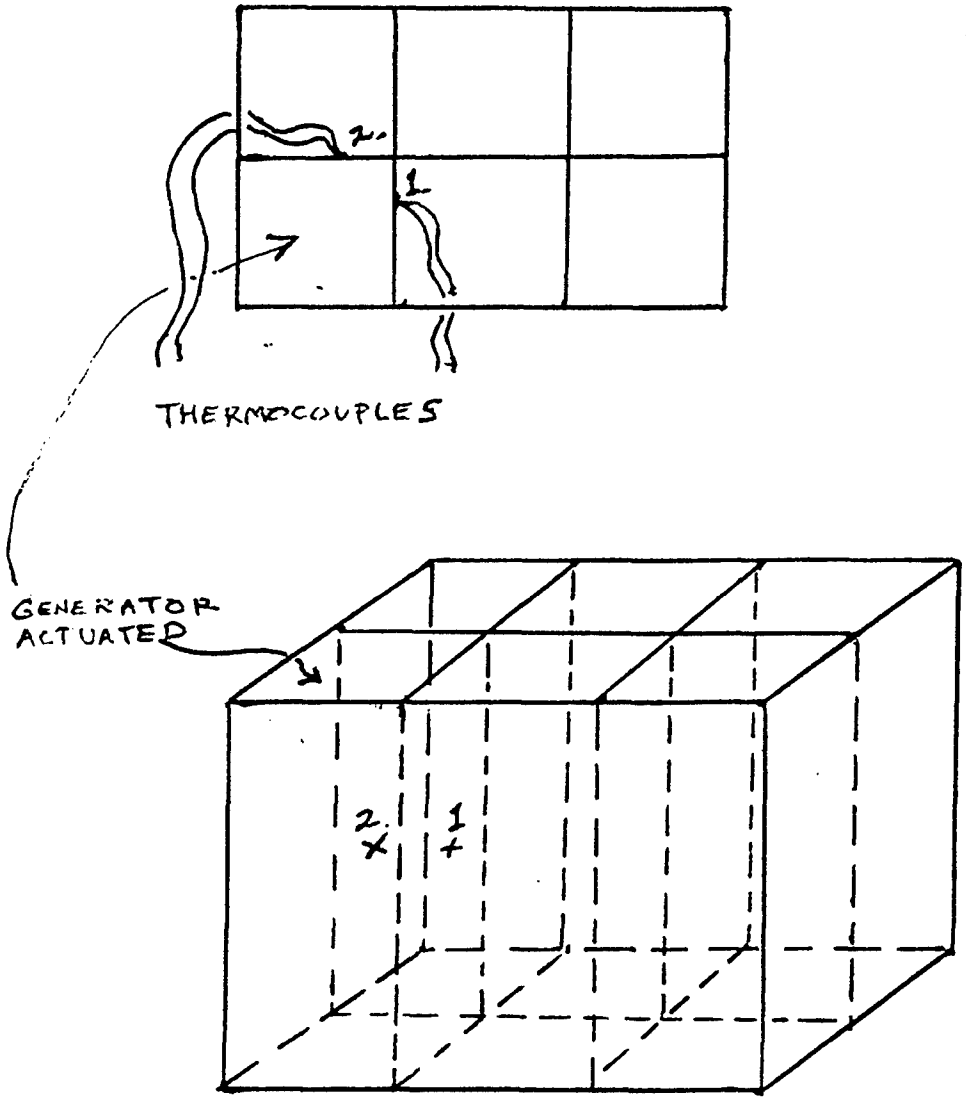


FIGURE 10 - Carton Thermocoupled for Test

Time (after ignition) (continued)	T.C. 1	T.C.2
32 minutes	133	133
34	135	136
36	137	139
38	140	141
40	142	145
42	145	147
44	146	150
46	148	154
50	152	158
55	154	163
60	156	165

Since only one primer was activated, the other primer probably actuated within seconds afterwards. The exact time, however, was not determined. The results of this test were that the tygon hose from the generator to the mask melted at several points with overall scorching noticeable. The breathing bag off the mask also melted and the outer polycarbonate housing softened and buckled around the vent ribs. There were no other signs of damage to the generator and no fire occurred at any point within the carton.

Test #9 - This test was conducted as the result of a direct AFOSI request. AFOSI had theorized that if an incendiary device had been placed in or upon the plywood crate before the fire then some foreign material (possibly containing hydrocarbon compounds) would be found in the debris.

Although repeated tests confirm the presence of some type of hydrocarbon in the ashes near the origin of the fire, the unknown appeared to be fragments of high molecular weight compounds that cannot be considered fractions or secondary products of liquid fuels such as gasoline or JP-4. Since a considerable amount of plastic and rubber are used in the candle housing and facepiece, the conclusions were that the breakdown products caused by melting or burning of these materials probably account for the hydrocarbons found in the ashes.

Test #10 - This experiment was an approach to determining the ignition temperature of generator accessory materials under high oxygen concentration. If, for example, the silicone rubber mask in the C-5A oxygen generator would ignite at 500°F in ambient air then the ignition temperature would certainly be reduced in an oxygen enriched atmosphere. This test was to determine concentration of oxygen in the mask compartment (recess) of the generator housing if the gas were permitted to flow freely into it.

A generator was modified to permit the oxygen evolving from the candle to flow freely into the mask compartment. The mask assembly remained in place. The generator housing wall adjacent to the mask compartment was tapped to allow a sampling tube to be inserted. After the unit was activated, gas samples were periodically drawn through the tube for analysis.

It was determined that for a period of 30 minutes 98-100% oxygen was present in the compartment.

Test #11 - In concluding the test already described, the conference re-convened to discuss the possibility of a final test covering a re-construction of the fire. The general consensus was that by repeating the fire under controlled conditions, it would be possible to study the pattern and rate of flame propagation. This information could then be correlated with the evidence gathered from the actual fire at Travis AFB. The ultimate goal to be achieved would be the determination of the cause of the fire - whether it be the malfunction of a C-5A oxygen generator or some other reason.

The aluminum seats pallets contained in the first three crates were inspected as a part of fire damaged material brought to the laboratory. The pallet that had been located in the bottom of the second crate indicated a complete "burn-through" in one area (approximately 3 to 4 square feet). No evidence of a similar damage was noted on the other pallets. It was concluded that such a burning through could only have been caused by a high intensity torching fire in close proximity. Normal burning of the class "A" materials present could not have resulted in this damage pattern. It was further concluded that the fire observed in Test #2 would not have provided the required intensity. Since

the only unusual contents in the crates from a fire standpoint were the oxygen generators, it was determined that the most severe fire conditions possible would be ignition within the carton containing six generators. This test was, therefore, calculated to provide the array of combustibles that would provide the most severe fire condition. The test observations would, therefore, be directed toward any indications of high intensity burning that might explain the above described burn-through.

In preparation for the test, a large plywood crate identical in size and shape to those which burned at Travis AFB was set up in an outdoor gun range. A carton containing six C-5A oxygen generators was placed inside the crate at approximate center, and covered with a polyethylene tarpauline (Figures 11 and 12). One of six generators was then modified so that oxygen would flow directly into the mask compartment. The tygon hose from the generator to the mask was fitted with a nichrome wire heating element. The generator was then activated and the lid of the crate was nailed down. Power was next applied to the heating element until the tygon hose temperature rose to the ignition point. The oxygen flowing through the hose blended with the molten tygon and initiated combustion. (It should be noted that positive fire ignition by nichrome wire had been previously verified in

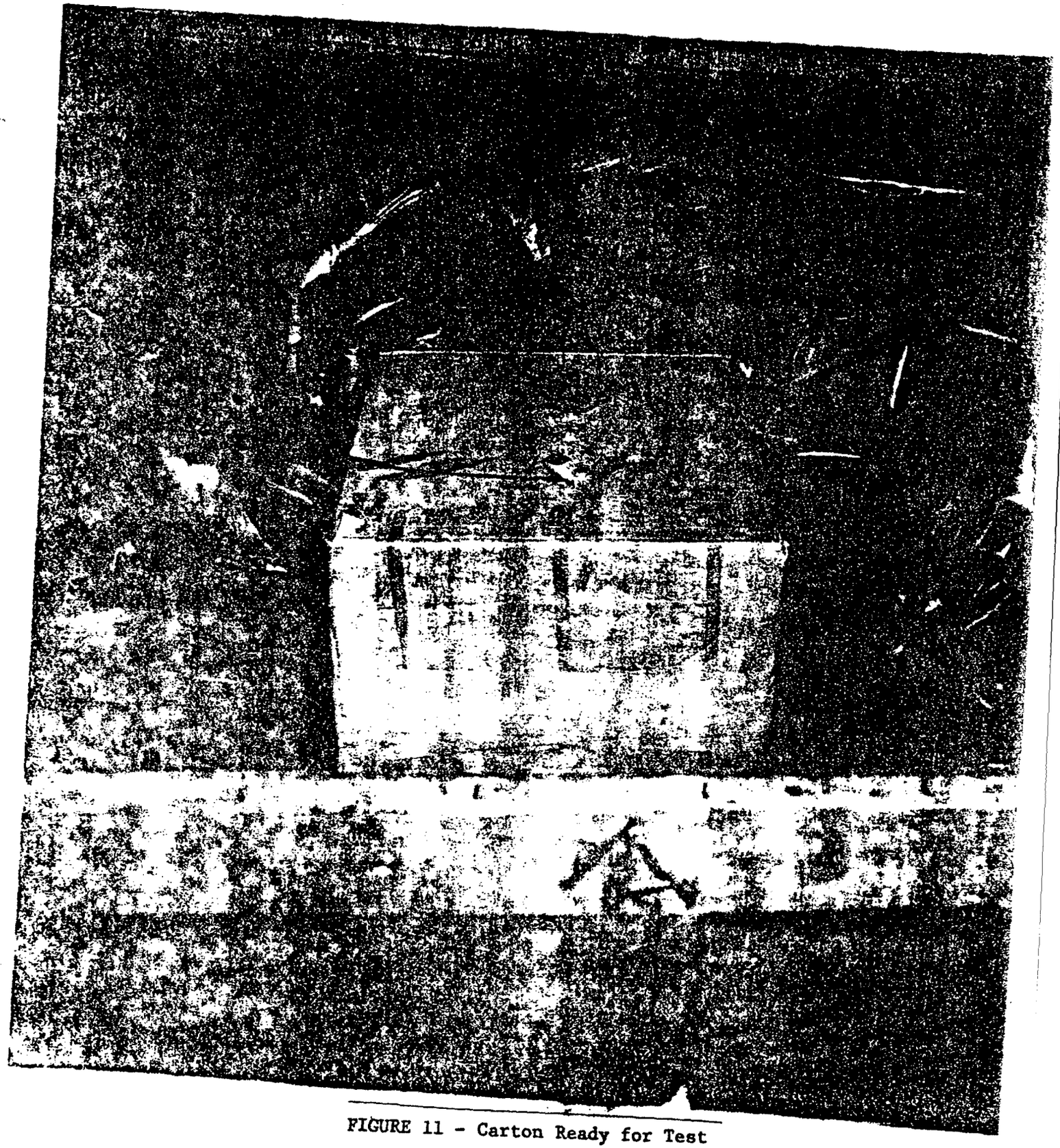


FIGURE 11 - Carton Ready for Test

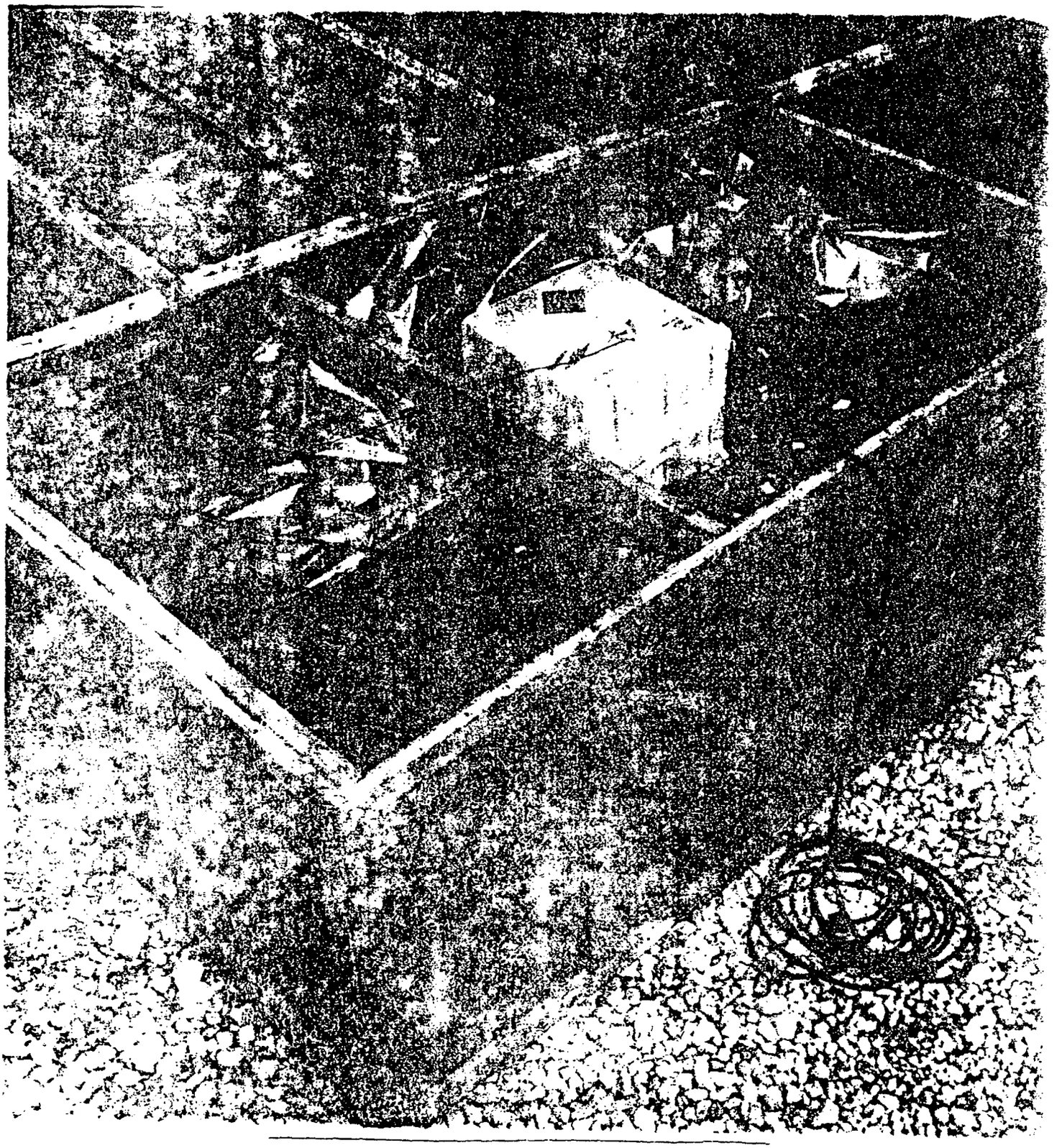


FIGURE 12 - Overview of Carton within Crate

in separate tests with individual generator packages. Thermocouple readings from the carton during this test also confirmed this mode of ignition.)

The entire test as it proceeded can be chronologically tabled as follows:

Time (minutes)	Event	Recorded Temperature
0	Generator Actuation	78°F
1-4	Crate sealed	-
4	Fire initiated	-
5		400°F (in mask)
8		1100°F (in mask)
16	Visible smoke from lid	-
20	Adjacent generator packages aflame	1400°F
29	Flames appear from crate lid	-
30		1500°F (max. temperature recorded)
36	Flame pattern identified	-
47	Fire extinguished - test terminated	-

The hole burned in the lid of the crate was two feet in diameter after 36 minutes into the test. The strong breeze present in the gun range took over at 36 minutes and distorted the path of the

flames on the crate lid. The fire was completely extinguished at 47 minutes. Figures 13 and 14 show the progress of the fire while Figures 15 through 18 depict the rubble inside the crate after extinguishment. The data and observations noted during the test fire contradicted the theory that an oxygen generator was the cause of the fire at Travis AFB. Despite the spread of the test fire, only one other generator (besides the one actuated) among the six was triggered due to heat. This generator was directly above the unit deliberately activated. The remaining four units showed no evidence of having been in an intensely hot fire. In fact, the interfaces of several of the individual generator packages were not even charred. In addition, the units were readily operable after the test fire had concluded. The spread of the fire inside the crate was such that the flames "wafted" rather than "cut" a hole in the lid of the crate such as would occur with an intensely hot fire yet an examination of the debris from the Travis AFB fire indicated that a "torching" type of fire had occurred. An aluminum pallet stored in the crate directly over the suspected origin of the fire had been "cut through" by a concentrated flame source. In addition to the type of blaze being different, the times required for both fires to "mature" were inconsistent. There had been no indication of fire at 1335 17 August 1973 at Travis, yet 25 minutes later at 1400 the blaze had raged out of control - flames engulfing the entire stack of

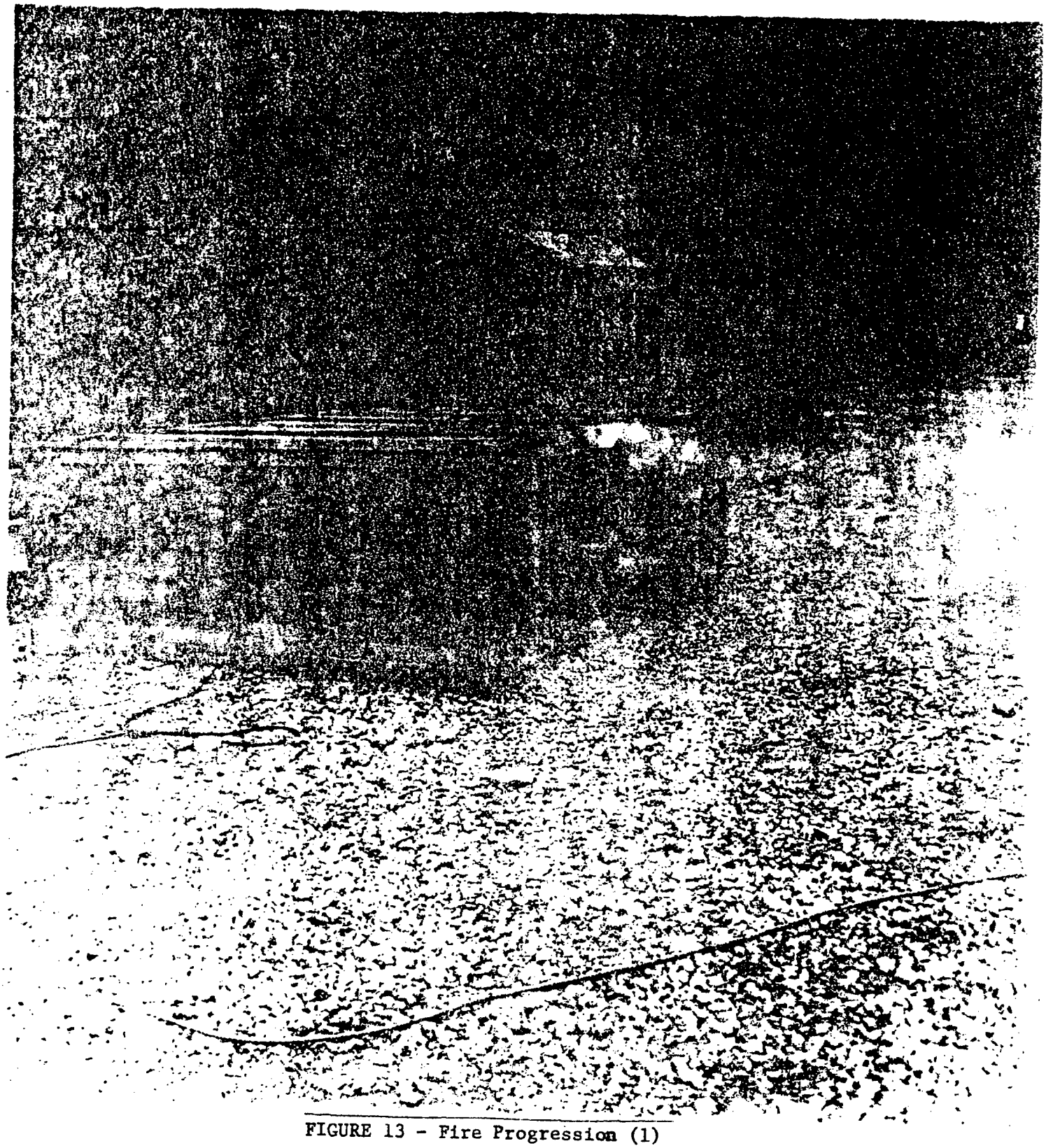


FIGURE 13 - Fire Progression (1)

FIGURE 14 - Fire Progression (2)

FIGURE 15 - Fire Debris (1)

FIGURE 16 - Fire Debris (2)

FIGURE 17 - Fire Debris (3)

FIGURE 18 - Fire Debris (4)

crates up to the windows high on the building wall. Yet in the test fire 25 minutes were required merely for flames to emerge from the crate in which the fire had been initiated. This fact apparently negates the possibility of the fire having started inside of a crate. On the other hand, if the fire had started on top of the crate then the next crate up would have ignited with the flame pattern spreading rapidly over the outside of the crate stack. The source of the fire meanwhile would have burned through the top of the crate on which it had rested.

IV. CONCLUSION:

The overall data and evidence gathered from the testing of the C-5A emergency oxygen generator resulted in the following conclusions:

In order for an oxygen generator of the type in question to have started the fire, two events would had to have happened. The first would be the auto-ignition of a generator either by the igniter hammer striking the primer or by an ambient temperature of at least 315°F. The latter proposition is impossible while the former is extremely improbable. There has been no recorded case with the C-5A oxygen generator (either under laboratory or field conditions) where a unit was accidently ignited by the restraining pin being jarred loose. The vibration and shock tests conducted within this program were at levels far in excess of anything existing at Travis AFB on 17 August 1973, and yet the restraining pins remained in place during tests.

The second occurrence which would have had to happen would be a "burn-through" of the housing of the generator after it had accidentally ignited. A "burn-through" of the housing could (but not necessarily must) cause a fire in the generator or adjacent material. It is emphasized that a generator accidentally igniting under storage conditions and operating normally would not cause adjacent material to burn. Figure 19 is a cross-sectional schematic of a hypothetical chlorate candle which developed a burn-through at the housing. The drawing illustrates that it is possible for the molten candle material to flow out of the generator housing. While "burn-through" occurrences have developed in chlorate candle oxygen generators, there is no record of any such case with the C-5A unit. Furthermore, the internal configuration of the C-5A unit is so designed as to prevent a "burn-through" from occurring.

Summarily, both of these events would had to have occurred in the same generator. Pre-conditions existing for either but not both events would not be sufficient for the generator to be the cause of the fire. Since the preponderance of evidence from the tests shows that neither event happened, the C-5A unit could not possibly have started the fire.

A final point can be made about the test fire. The spread of this fire was typical of burning cardboard and plastics and was not unusually

accelerated by oxygen generation or the grouping of six units together. Therefore, the combustibles known to be present in the Travis AFB fire incident do not account for the nature of the resulting damage. This strongly indicates the presence or addition of combustible material at the fire scene unknown at this time to laboratory investigators.

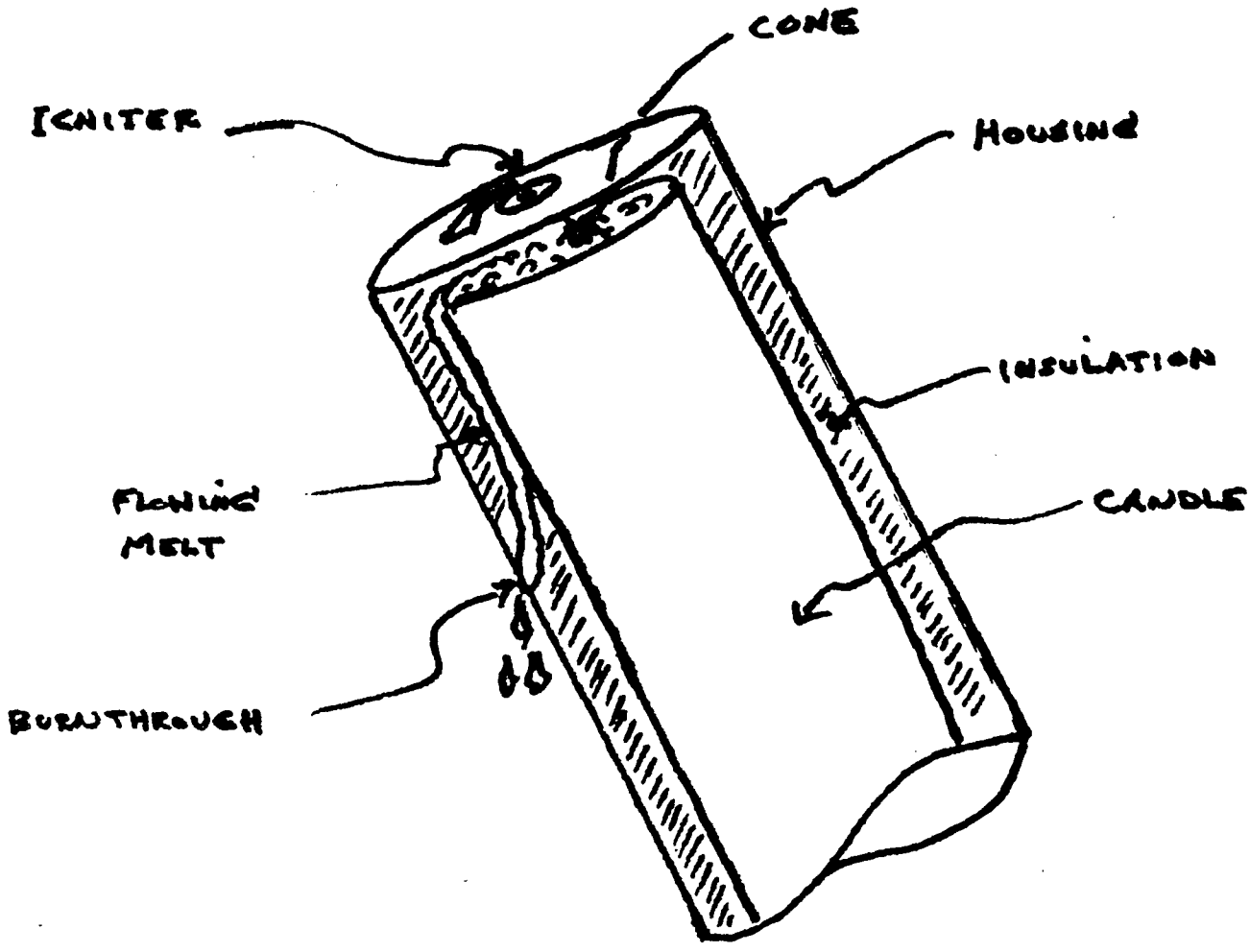


FIGURE 19 Chlorate Candle Housing "Burn-Through"

V. REFERENCES:

1. Memorandum, Col. B. J. Massingill to General Germfraad Hq. MAC; dated 6 September 1973, concerning possible causes of fire at Travis AFB, Calif. on 17 August 1973.

2. Teletype, AFOSI to AFFDL/FEE, et al; dated 15 September 1973, concerning OCAMA/Tinker AFB interest in fire at Travis AFB.

3. Joint Messageform, AFOSI/WPAFB to AFOSI/Travis AFB; dated 26 September 1973, subject: Interim Report on AFFDL/FEE Test of C-5A Oxygen Generator.

4. Specification, C-5A oxygen generator, Lockheed-Georgia Company, dated January 1968.

5. NFPA (National Fire Protection Ass.) document, Fire Hazards in Oxygen Enriched Atmospheres, 1969.

6. Technical Memorandum AFFDL-TM-70-7-FEE, "Test of State-of-the-Technology Solid Chemical Oxygen Generators for Aircraft Applications," October 1970.

7. Test report "Evaluation of Chlorate Candle Under a Simulated Fire Environment," October 1973, G. Gandee, R.Cretcher and B. Botteri.

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

MEMORANDUM FOR DTIC/OCA 11 May 00

FROM: Det. 1 AFRL/WST

SUBJECT: Reclassification of ADB 214 862

Please change the distribution of the following report to "Approved for public release; distribution unlimited." The report was clear for public release, 11 May 00 (ASC 00-1064):

ADB 214 862 AIR FORCE FLIGHT DYNAMICS LAB WRIGHT-PATTERSON AFB OH Test Evaluation of the C-5A Emergency Oxygen Generator as a Possible Causative Agent of Fires. Thompson, Edward B., Jr. Oct 1973. AFFDL-TM-73-136-FEE

JOSEPH A. BURKE
STINFO Team Coordinator
Technical Information Division
DSN 785-5197